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UNITED STATES DEPARTMENT OF AGRICULTURE

BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

FOREST INSECT INVESTIGATIONS

REPORT OF

CARPENTER ANT CONTROL INVESTIGATIONS

at

PACK FOREST,

LaGRANDE, WASHINGTON.

By
R. L. Furniss
Assistant Entomologist

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445 U. S. Court House,
Portland, Oregon,
February 1, 1938.

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SUMMARY

Results of experimental control of carpenter ants at the Pack Demonstration Forest, LaGrande, Washington, are herein reported. Twenty-three chemicals and combinations were tested on colonies living in logs and stumps in the woods for the purpose of finding the most promising materials for control in infested homes.

Three species of carpenter ants were encountered in the experiments: namely, Camponotus laevigatus (F. Smith), C. maculatus vicinus Mayr var., and C. herculeanus modoc Wheeler. In homes only C. maculatus vicinus var. has been definitely identified.

Four methods of treatment were employed as follows:

(1) A contact insecticide was sprayed upon exposed ants.

(2) Poison dust was placed in and near ant colonies.

(3) Poison bait was placed near ant colonies.

(4) A fumigant or combination fumigant and contact insecticide was injected into ant galleries.

Standard Oil Fly Spray, a contact insecticide composed of pyrethrum extract in light oil, was very effective when applied to the exposed ants.

Sodium fluoride and sodium fluosilicate were dusted into ant runways. Both were applied under adverse conditions; therefore, they are to be retested, especially since sodium fluoride gave some promise of success.

Two baits containing Paris green and one containing thallium sulphate were ineffective measures of control. Additional tests are to be made with Paris green in order to check the method of application. Thallium is considered as being too toxic to man and higher animals for general use as an insecticide.

Seventeen materials were injected into carpenter ant colonies to act as fumigants or combination fumigants and contact insecticides. Best results were obtained with carbon disulphide, carbon tetrachloride, ethylene dichloride, paradichlorobenzene, in fuel oil, and naphthalene in fuel oil. When all things are considered, a mixture of carbon tetrachloride and ethylene dichloride seems most promising. Actually this combination was not tested, but since these two chemicals gave good results separately it is planned to try this mixture.

INTRODUCTION

The Problem. In the Pacific Northwest carpenter ants are serious pests in dwellings and other buildings. This condition is probably brought about by the fact that much of the land has been recently cleared of forests. Even in large cities like Portland many of the residential sections are literally "carved out of the woods". As a result, stumps and fallen logs, which harbor carpenter ant colonies, often occur in proximity to homes. Furthermore, numerous coniferous trees, principally Douglas fir, are left as ornamentals. These trees also act as feeding grounds for aphids, which in turn supply carpenter ants with food. It is but a step from this condition to the establishment of carpenter ant colonies in homes.

That carpenter ants do build colonies in houses is abundantly evidenced by the number of requests for control that are received each year at the Forest Insect Laboratory in Portland. During 1937 an accurate record was kept of all requests for information concerning insects. From a total of 172 calls, ants topped the list with 24. Of these calls, 16 concerned Camponotus (3 more than the total inquiries relative to termites, the next most frequently reported insects). In this connection it is noteworthy that home owners frequently confuse ants with termites.

The present study was brought about by the fact that control measures developed elsewhere and recommended for control in the

Portland area have given very irregular results. Some cases of satisfactory control have been reported, while in other instances no relief was afforded by the suggested treatments. Depending upon the circumstances in a given case, one of three measures has usually been advocated: (1) expose the colony and eliminate mechanically or spray with a contact insecticide; (2) use sodium fluoride dust in galleries and runways; (3) apply a bait composed of Paris green and fatty hamburger.

Objectives. Investigation of carpenter ant control measures was begun in order (1) to test the effectiveness of previously recommended insecticides and (2) to determine the best methods of application. It is believed that these major objectives can best be attained by:

(1) Conducting tests in the woods where numerous ant colonies can be obtained. Furthermore, treatments and examinations can be conducted without hindrance.

(2) Conducting tests in infested homes to determine the effectiveness of the more promising materials as indicated by the field tests.

(3) Determining the species involved, their habits, and reaction to insecticides.

Acknowledgments. The preliminary field tests herein discussed were conducted in August, September, and October, 1937, on the Pack Demonstration Forest at LaGrande, Washington. Through

a cooperative agreement, a field laboratory, an insectary, and the use of other facilities were contributed by the University of Washington College of Forestry. Dr. Walter Meyer, Prof. J. L. Alexander, and Mr. D. M. Covington of the College faculty all aided materially in the establishment of the field laboratory which is to be used not only for carpenter ant studies but for other forest insect problems in the Douglas fir region. Mr. Daniel Bonnell, acting as Field Aide, assisted in the establishment of the laboratory and also conducted the ant control tests that were run in August. To all of these men thanks are now extended.

Location of Field Tests. The actual tests were conducted on colonies in stumps and fallen logs scattered over approximately a section of land, located entirely on the Pack Forest. Most of the thriving ant colonies were found in openings located in stands of Douglas fir reproduction. In these openings the stumps and fallen logs were usually "case-hardened" on the outer portion, a condition that the ants apparently found quite suitable for their development. In all stands in which the canopy was closed, the down logs were wet and rotten with very few carpenter ant colonies. In open areas where there were many logs and stumps but no Douglas fir reproduction, few Camponotus were found. From this it is concluded that a certain condition of the

wood is necessary, and in addition it seems probable that colonies are normally established where the ants have access to aphids feeding upon Douglas fir.

Ant Species in Field Tests. During the tests collections were made from nearly all of the treated colonies. This entire lot of material has been determined by Dr. M. R. Smith of the Division of Insect Investigations, U. S. Bureau of Entomology and Plant Quarantine. He found that of the 100 carpenter ant colonies from which material was obtained 68 were Camponotus laevigatus (F. Smith), 26 C. maculatus vicinus Mayr var., and 6 C. herculeanus modoc Wheeler. Two colonies of Lasius niger var. sitkaensis Perg. and one of Formica fusca var. subaenescens Emery were also encountered, but these species were not abundant enough for control tests.

Ant Species in Homes. C. maculatus vicinus var. has been definitely determined from specimens collected in Portland homes, and C. laevigatus is strongly suspected of being present, and may be more abundant than the former. Lasius niger sitkaensis Perg. is a frequent inhabitant of homes where it appears to build its chambers in moist, rotten wood that has been worked by the damp wood termite, Zootermopsis angusticollis Hagen. Lasius is especially troublesome during the flight period in the fall when great numbers often appear in houses.

Identity of the Species. The following key is one prepared largely by Dr. M. R. Smith. It is for the separation of those

ants which are most likely to be found in homes in Washington and Oregon.

1. Workers strongly polymorphic; color predominantly black; size of workers 6 mm. or larger. Camponotus, 2.

   Workers not polymorphic; color reddish brown; size of workers 4 mm. or smaller.....
   .....Lasius niger sitkaensis Perg.

2. Clypeus without longitudinal carina..... 3.

   Clypeus with a longitudinal carina; color of thorax highly variable.....
   ..... Camponotus maculatus subsp. vicinus Mayr var.

3. Body shining black, very pilose.....
   ..... Camponotus laevigatus (F. Smith).

   Body opaque, black, with reddish-brown legs.....
   ..... Camponotus herculeanus var. modoc Wheeler

Amount and Nature of the Damage. No survey has been made in the Pacific Northwest to determine the amount and nature of damage to buildings caused by carpenter ants. General observations, however, indicate that they seldom cause much structural damage, although their presence in homes is quite prevalent. They are more likely to be troublesome during the flight period when the winged forms often emerge in infested homes. Since carpenter ants do not feed upon wood, they are likely to take advantage of openings between floors and walls rather than tunnel through timbers. Their galleries, which are sometimes in dry, unrotted wood, may extend to any part of a dwelling. Additional information is needed relative to the status of carpenter ants in this region.

METHODS AND MATERIALS

On the Pack Forest the colonies were located, in so far as possible, by external evidences such as activity of workers or by piles of boring dust near the infested logs. Figure 1 shows a log containing a large colony of Camponotus that was easily located by the refuse pile. Some of the colonies were partially exposed with an axe. This latter procedure was more and more necessary as the season advanced, for ant activity nearly ceased and most of the external evidences of ant inhabitation were washed away by rain. After the colonies were located they were staked, numbered, treated, and after a variable interval reexamined for evidences of mortality. Four methods of treatment were applied.

Method 1--Treatment of Exposed Colony. One of the best control measures is to expose the entire colony and apply some insecticide that will kill all of the ants. This is easy to do when a colony is in a log in the woods. Occasionally this method can be used in homes or other buildings. Often, however, colonies in homes are so situated that anything short of tearing the house down would fail to expose the colony sufficiently for extermination.

One material, Standard Oil Fly Spray, was tested. It was applied to the exposed ants by means of a small garden-type hand sprayer which worked satisfactorily.

Method 2--Dusting in Runways. The principle of this treatment is that certain poisonous dusts, when placed in the ant runways, will adhere to the ants during the course of their activity. Subsequently, when the ants groom themselves and each other, the dust is taken into their digestive system where the toxic effect is by stomach poisoning. Supposedly ants that have dust on their bodies will carry it to others within the colony and extermination of the colony will result.

Two chemicals, sodium fluoride and sodium fluosilicate, were used for this purpose. Holes were bored into the logs in such a way that the galleries were tapped. Dust was applied with a small hand duster equipped with a metal extension tube and then the holes were covered with dirt. Dust was also scattered on and under the logs where the ants were likely to walk.

Method 3--Baiting. Various chemicals worked into foods are often used to poison ants. Several different baits of this kind have been suggested for carpenter ant control. Extreme care must be used in the application of these poisons in order to prevent consumption by human beings or domestic animals.

Paris green and hamburger; Paris green and brown sugar; and a mixture of thallium sulphate, honey, and sugar were the three baits used in the tests at the Pack Forest. All were applied in the same manner. The bait was placed in 12-oz. baking powder cans which had previously been perforated with 3/4 inch holes. Three

cans containing equal amounts of poison were placed near each colony in places frequented by the ants. Often the bait cans were placed within a few inches of entrance holes leading to the colony.

Method 4--Fumigants and Contact Insecticides in Ant Chambers. A great many materials have been recommended for killing carpenter ants by fumigation or contact in galleries. These materials can be used when the position of the ant gallery is known but the ants cannot be readily exposed. When the colony is localized and the limits determined many chemicals can be used to good effect. Under these conditions, however, it is often possible to expose the colony and actually destroy it. In fumigation the difficulty lies in reaching all of the chambers. Often only a single passageway can be located, whereas the main colony may be in some remote part of the home--even on the second or third floor. Under these conditions a fumigant is of little use. When a colony is well localized certain liquids can sometimes be introduced into the galleries and the ants killed by contact. Even when the exact situation of a colony is known the torturous nature of the chambers may baffle thorough fumigation. Since many of the fumigants are extremely volatile and consequently inflammable, extreme care must be exercised in their use.

At Pack Forest the colonies were treated by boring holes into the chambers. When liquids were used, part of the material

was applied with a hand-type spray gun in order to secure good distribution in the galleries. Some of the liquid was also poured into the chambers through a funnel. After treatment the holes were closed with dirt. In the case of solids the material was tamped into holes which were then covered. Seventeen chemicals and combinations were used as follows:

Carbon disulphide, 2 tests.
Carbon disulphide and carbon tetrachloride.
Carbon tetrachloride.
Carbon tetrachloride and Pyrocide 20.
Orthodichlorobenzene.
Orthodichlorobenzene and cottonseed oil.
Trichlorobenzene.
Paradichlorobenzene, 2 tests.
Paradichlorobenzene and fuel oil.
Naphthalene.
Naphthalene and fuel oil.
Turpentine.
Turpentine and kerosene.
Ethylene dichloride.
Dichloroethyl ether, diluted.
Dichloroethyl ether, undiluted.
Hexachloroethane.

1937 FIELD TESTS

The purpose of these field tests was to determine the most effective of the many materials that have been suggested for carpenter ant control. Later these promising chemicals will be retested in infested homes. For comparative purposes, the ideal material for carpenter ant control has been defined as meeting the following requirements. In some cases chemicals were excluded from further consideration merely because they possessed some

particularly undesirable attribute to such a degree that use of them in homes could not be recommended, although in other respects they might closely approach the ideal.

The ideal material for carpenter ant control

(1) must be effective in killing ants;

(2) should be:

(a) of low cost,

(b) of non-offensive odor--at least the odor should not persist,

(c) readily available,

(d) easily applied,

(e) harmless to interior finishes,

(f) non-explosive and non-inflammable,

(g) non-poisonous to man and higher animals.

A summary of all of the 1937 tests is given in Table I, in which are tabulated the date treated, duration of test, amount of chemical used per colony, number of colonies treated, effectiveness of the treatments, species of ant in each colony, and other pertinent data relating to the experiments. Most of the tests were conducted late in the fall when nearly all of the ants were within the colonies. This was a favorable time for the fumigation tests, but for the dusting and baiting experiments it was not.

In the following tests per cent of mortality is not wholly to be relied upon for a comparison of the effectiveness of the

various chemicals. This is especially true of the chemicals that were injected into colonies to act as fumigants. Most of the materials that were used will kill ants when poured directly upon them, as was often the case when small colonies were tested. The object was to find some material that would disperse widely throughout the colony and act as a fumigant. Those chemicals that seemed to have this property in greatest degree were considered promising.

Method 1--Treatment of Exposed Colony.

Standard Oil Fly Spray. This material was tested for the purpose of finding some material that can be used to kill an entire colony, once the ants are completely exposed. It is typical of that class of insecticides consisting of pyrethrum in kerosene or kerosene-like oil. Materials of this type are comparatively cheap, readily available, and easily applied.

Standard Oil Fly Spray was effective in killing all ants that were appreciably wetted by it. As soon as the liquid was applied, the ants showed marked signs of distress by first running about very rapidly; then they would drag their bodies upon whatever surface was at hand, apparently in an attempt to dislodge the irritation; soon after, they doubled up and attempted to clean themselves with their mandibles; and finally, about three minutes after the initial application, most of the ants ceased to move. Movement of a few ants persisted as long as ten minutes.

Three small colonies that were completely exposed at the time of treatment were exterminated. Three large colonies were only partially exposed. Thirty-three days after treatment the logs were revisited, at which time numerous ants were still alive and active in the three large colonies.

It is evident from the tests that Standard Oil Fly Spray is a satisfactory contact insecticide for the control of ants--provided that all of the ants are covered with the spray during the treatment. Limitation of the use of this and similar materials lies in the fact that in homes and other buildings ant colonies are frequently so located that they cannot be uncovered. No further tests with Standard Oil Fly Spray are contemplated.

Method 2--Dusting in Runways.

Sodium fluoride dust. Sodium fluoride has been reported to be an effective control for carpenter ants (1, 2, 5, 11).[1/] It has also been recommended for the control of termites (9). Wardle (18) states that, while the main insecticidal value is as a stomach poison, it irritates the outer skin of insects, causing them to draw their antennae and tarsi through their mouths, thus introducing the poison into the digestive tract. It is an effective insecticide only when dry. Sodium fluoride has many advantages as a material for carpenter ant control. It is non-expensive, easily applied, readily available, and relatively non-toxic to man and higher animals.

1/ Numbers in parentheses indicate "Literature Cited", p. 40.

Through a misunderstanding, Test 1 was applied improperly. The colonies were thoroughly opened and dust was applied to the exposed ants. A reexamination was made 31 days after the treatment, when all colonies were abandoned except one in which about 75 ants were still present near a pile of sodium fluoride dust that had long since become compacted by fall rains. No dead ants were found in any case. This test was conducted in such a way that the mechanical disturbance was so great that the colonies probably would have moved even had no chemical been applied.

Since the first test was not properly conducted, a second attempt was made. In Test 2, the dust was applied as described in Method 2 on page 9. Many of the ants were covered with dust. This had no immediately noticeable effect, although some did stop to groom themselves. At one colony, soon after treatment several ants emerged from the log with particles of sodium fluoride which were deposited on the refuse pile. Apparently they were attempting to free their passageways that had become clogged with chemical.

On the day following treatment a large colony of Camponotus laevigatus was examined externally. Numerous workers were actively removing dust and borings from the colony. Many were fairly covered with sodium fluoride. Four ants still showing faint movement were curled up on the refuse pile and a fifth was apparently dead, presumably as a result of the poison. Seven days after treatment about 100 dead and dying workers were noted on the refuse pile of this colony.

Two weeks after treatment all of the colonies in Test 2 were revisited and partially opened. No dead ants were noted either in or near two colonies, one containing Camponotus maculatus vicinus var. and one containing C. herculeanus modoc. In two colonies known to contain C. laevigatus a few ants were dead in the chambers and on the refuse piles. In one colony suspected of harboring C. laevigatus (see Fig. 1) a great many workers were dead on the refuse pile. It is estimated that in no case had more than ten per cent of the colony been exterminated. Four partially opened colonies have been left for a final examination in the spring of 1938.

During October while Test 2 was being made there was a heavy dew each night which left the ground wet until about noon of each day. As a result, the dust outside the logs soon became paste-like and of little value as an insecticide. Furthermore, because the fall rains had begun, the ant galleries were quite damp. The net result of this was that the dusting treatments were made under very adverse conditions.

While sodium fluoride dust did not exterminate any colony, in fact did not greatly reduce the number of ants in any colony, it is considered to have considerable promise. It was applied under adverse weather conditions while the ants were inactive and the chemical soon became useless. In a home these conditions would not be found. The crux of the problem is to determine its

effectiveness. Further extensive tests will be conducted both in the field and in homes.

Sodium fluosilicate and bentonite, 7:3. Sodium fluosilicate is very similar to sodium fluoride both in appearance and insecticidal properties (18). It has been used effectively on many insects, including termites. In the test at Pack Forest bentonite was added to improve the physical properties of the dust.

The dust was applied late in October under very unfavorable climatic conditions. Six days later two of the colonies were partially exposed but no dead ants were found either in or near the colonies. By this time the dust outside of the logs had become thoroughly wet by dew and rain so that it was probably no longer a useful insecticide. Part of the exposed colonies, together with the undisturbed colonies, were left for a spring examination.

The test was unsatisfactory and justifies no conclusions. Additional field tests are to be made in the spring to determine the effectiveness of sodium fluosilicate.

Method 3--Baiting.

Paris greenand hamburger, 1:30. This bait has at various times been reported as an effective control of carpenter ants (2). It has been recommended for use in Portland homes, but little information is available as to the results. Paris green, an acetoarsenite of copper, is poisonous to man and must be handled accordingly.

On August 25 three bait cans (prepared as in Method 3, page 9) were placed near each of five logs that supposedly contained carpenter ants. Thirty-three days later when the logs were cut apart only two of them contained carpenter ants. Both of these were large, active colonies, but contained no dead ants. There are three possibilities explaining the uninhabited logs: there may have been no ants present at the time of treatment, the ants might have been disturbed at the time of the original examination and subsequently moved, or the presence of poison bait may have repelled them. The first is considered as most probable.

This baiting method, together with the two following, may have failed because of an abundance of aphids on the nearby Douglas fir reproduction. As late as October 14 the ants were seen attending these aphids. The aphid honeydew may have served as an abundant reservoir of attractive food, causing the ants to overlook or avoid the poison bait. It is a well-established fact that ants will often shun a bait which at other times is quite attractive to them.

While baits in infested homes might prove more attractive to ants than in the field tests, it is probable that the ant and aphid relationship would exist there also. In most of the cases of infested homes that we have seen, Douglas fir trees have been available close at hand. These trees could very likely harbor the aphids which carpenter ants attend. Furthermore, we have received

no complaints of carpenter ants getting into foodstuffs, an indication that ants in homes are feeding elsewhere.

At present no definite conclusions are justified relative to the effectiveness of the Paris green-hamburger bait. Additional field tests will be made keeping a closer check on the attractiveness of this bait. It should also be tested experimentally in a few infested homes. A more satisfactory container might be developed.

Paris green and brown sugar, 1:32. This bait was tested in the same manner as Paris green and hamburger.

Approximately one month after treatment the logs were cut open and examined. Ants were found alive and active in all of the five colonies with no evidences of mortality.

Additional field tests will be made in the spring when particular attention will be given to the attractiveness of the bait.

Thallium sulphate bait. Thallium is a cumulative poison of high toxicity to man and animals and is without taste, smell, or other warning property. It has been used for rodent control, but is not recommended for general use because of its extremely poisonous nature (12a). Several workers have found that thallium sulphate bait is an effective control for carpenter ants.

A bait was prepared according to a formula proposed by Flint and McCauley (6) and was placed near five colonies in the same manner as the two preceding baits.

Formula

Thallium sulphate	Dissolve 2 grams in 8 fluid ounces of lukewarm water and add to syrup composed of:
Granulated sugar	1 pound
Strained honey	3 ounces
Glycerin	1½ fluid ounces
Water	8 fluid ounces

Upon examination at the end of 33 days, four colonies of Camponotus laevigatus showed no evidences of mortality. A single colony of Formica fusca var. subaeneecens Emery contained about 30 per cent dead ants.

Lack of successful control with this bait, as well as with the Paris green baits, may have resulted from failure to renew the bait at frequent intervals. At the suggestion of Mr. S. A. Rohwer, tests with thallium are being discontinued. Irrespective of any possible successful control with this material, its extreme toxicity is such that it should not be recommended for general use. Even the handling of thallium is detrimental to human well-being.

Method 4--Fumigants and Contact Insecticides in Ant Chambers.

Carbon disulphide. Carbon disulphide forms a heavier-than-air gas that is very toxic to ants and many other insects. Its disadvantages are: an extremely disagreeable odor; an inflammable, even explosive nature; and the fact that the injection must be from above the entire colony. (The latter is occasionally an advantage.) It has been generally recommended as an ant fumigant

(5, 11). In New England, MacAloney and Hosley (10) found that carbon disulphide is effective in the control of the mound-building ant, Formica exsectoides Forel.

In this and the following tests the chemical was applied in the manner described on pages 10 and 11. A pint of carbon disulphide was injected into each colony. All of the ants in three of the four logs that contained carpenter ants were killed, but in the fourth log only 50 per cent were killed.

It was evident from the test that carbon disulphide will exterminate an ant colony, provided that it reaches all of the chambers. This very important limiting factor is the key to its effectiveness. The same disadvantage applies to all materials that act as fumigants in the ant galleries.

Under the conditions prevailing in the field test, the colonies were undoubtedly treated under nearly ideal conditions. The position of the galleries could be determined with a fair degree of accuracy and the liquid was applied from above. In homes these conditions would seldom prevail.

The effectiveness and limitations of carbon disulphide have been sufficiently tested to show that no further field tests are necessary. Under certain conditions, when its strong, disagreeable odor and its explosive nature can be disregarded, it can be recommended for carpenter ant control because of its excellent insecticidal value.

Carbon disulphide and carbon tetrachloride, 1:3. In an attempt to secure some less inflammable material than carbon disulphide, it was combined with carbon tetrachloride, a solvent of some insectidal value as a fumigant. Wardle (18) states that a mixture of carbon tetrachloride and carbon disulphide does not reduce the liability of the latter to explode, since the two gases tend to remain separate. The explosion, however, may be extinguished almost immediately by the presence of non-inflammable carbon tetrachloride.

From 10 to 20 ounces of the mixture were injected into each of five logs and allowed to remain five days, at the end of which time the odor of carbon disulphide was still pronounced when the logs were opened. One log contained no carpenter ants. In the remaining four, estimated mortalities were 10, 90, 95, and 100 per cent. Apparently, lack of adequate distribution of gas into all of the chambers was responsible for the irregular results. Perhaps some additional mortality would have occurred in the partially successful cases if the tests had been allowed to run longer.

It is concluded that this mixture, which is somewhat safer to use than carbon disulphide alone, is effective under certain conditions. No further investigation of its effectiveness is planned.

Carbon tetrachloride. Carbon tetrachloride is a well-known fumigant, but it is considered to be of low toxicity to insects (13). Because of its inoffensive odor and non-inflammable nature, it has been frequently used as a substitute for carbon disulphide.

The test at Pack Forest was allowed to run for a period of seven days, at the end of which time no odor of chemical was present. In the four logs containing carpenter ants, mortalities were estimated at 0, 90, 90, and 100 per cent. As in the two preceding tests, distribution of the chemical was the factor which limited the amount of kill.

It is concluded that carbon tetrachloride is effective within certain limits. The results obtained in 1937 justify additional tests with this material.

Carbon tetrachloride and Pyrocide 20, 4:1. This mixture is non-inflammable by ordinary tests and has been found to be an effective spray against mosquitoes. Normally it should be used as a spray upon the exposed ants, as with the kerosene-pyrethrum type of spray.

At Pack Forest six to eight ounces of the liquid were introduced into the ant galleries with the thought that it would act as a combination contact insecticide and fumigant.

As applied, this mixture was unsuccessful. In four colonies containing carpenter ants, not over 25 per cent mortality

(0, 0, 5, and 25) was secured in any instance. This was rather surprising in comparison with the results obtained from carbon tetrachloride alone.

On the basis of the tests to date, the mixture of carbon tetrachloride and Pryocide 20 (pyrethrum) is unsuited for injection into the galleries. Tests will be made using it as a contact insecticide on the exposed carpenter ants.

Orthodichlorobenzene. Orthodichlorobenzene, which has been recommended for control and prevention of attack by termites, is a liquid which slowly gives off a heavier-than-air gas. It has also been recommended for control of carpenter ants (15).

At Pack Forest five logs were treated by injecting the chemical through bored holes. A sixth log was opened and the exposed ants were thoroughly wetted with a hand sprayer.

The ants that were sprayed did not die immediately. Most of them showed movement at the end of three hours; however, all were dead within 24 hours. In this case the ants were thoroughly soaked with the liquid, much more so than would be the case in ordinary treatment. On the strength of this, orthodichlorobenzene does not seem to be well adapted for use as a spray against carpenter ants--at least, it is not quick-acting.

At the end of 26 days the injected logs were opened and a pronounced odor of chemical was noted in all cases. Three logs contained carpenter ants. In one case complete kill was secured,

in another approximately 35 per cent, and in the third less than 10 per cent. In the colony in which the least mortality occurred, penetration of the chemical appeared to be good.

It is considered from these tests that orthodichlorobenzene is not a good fumigant for use against carpenter ants. The persistent strong odor would be an objectionable feature for use in homes. No further tests are contemplated.

Orthodichlorobenzene and cottonseed oil, 1:1. This mixture was tried at the suggestion of Dr. B. H. Wilford, who found that most interior finishes are not harmed by it.

The test was allowed to run five to seven days in late October. When the logs were opened, four contained carpenter ants. Estimated mortality in these colonies was 15, 50, 90, and 100 per cent. In the case of complete control, the liquid had been poured directly into restricted chambers containing a small colony. Odor of the chemical was still pronounced when the logs were opened. Action seems to have been more by contact than through fumigation.

No advantage was evident in the use of this mixture as compared with orthodichlorobenzene alone. The same disadvantages apply to both; therefore, no further tests will be made with the orthodichlorobenzene-cottonseed oil combination.

Trichlorobenzene. This volatile, colorless solvent was tested also at the suggestion of Dr. Wilford. Data are not available relative to its use as an insecticide.

At Pack Forest its value both as a contact insecticide and as a fumigant was tested. In the first test a colony was opened and the exposed ants were sprayed with the liquid. As soon as the ants were contacted with the liquid they ran frantically about. Within a minute or two they lost their footing and were unable to rise, although motion of their appendages continued for a long time. Fifty ants were thoroughly soaked with trichlorobenzene and placed in a baking powder can for observation. Movement of the legs and antennae continued at the end of 3½ hours. Death occurred before the next day.

As a test of the fumigant value of trichlorobenzene, five logs were injected with the undiluted chemical. At the end of 13 days all of the logs contained active ants. Estimated mortalities were 0, 35, 50, 50, and 75 per cent. Survival was in the upper chambers, in several instances very near the injection points.

The tests indicate that trichlorobenzene is not suited for carpenter ant control, either for contact or fumigation purposes. Its high cost and relative unprocurability are additional drawbacks to its use. No further tests are planned.

Paradichlorobenzene. Crystalline paradichlorobenzene is a well-established insecticide that has been successfully used as a soil fumigant against termites and orchard tree root borers. MacAloney and Hosley (10) found it ineffective for use against the

soil-inhabiting ant, Formica exsectoides Forel. Wardle (18) states that at temperatures above 74° F. paradichlorobenzene has a paralyzing and toxic effect upon insects. It is slow to vaporize and forms a heavier-than-air gas.

Two tests of five colonies each were run at Pack Forest. In Test 1 the crystals were applied in an unsatisfactory manner for a fumigant--that is, the nests were broken open and the crystals dumped upon the exposed ants. Even so, at the end of a month dead ants were found in four of five logs treated, and no living ants were present.

Test 2 was applied in October by tamping the crystals into holes bored in the logs and then covering them with dirt. Thirteen days later, three of the colonies were examined. A few dead ants and many living ones were found. The unexamined portions of these colonies, together with the two undisturbed colonies, were left for a spring examination. At that time it will be possible to determine whether paradichlorobenzene is suited for fumigation of carpenter ant colonies during the fall when temperatures are lower than the minimum advised by Wardle (18).

No additional tests are planned until the results of the spring examination are known.

Paradichlorobenzene and diesel oil (3 parts 27API:1 part 34API), 180 grams in 1 gallon. This combination has proved quite successful in experimental control of the western pine beetle in

ponderosa pine bark (17). The principle in ant control is that the oil carrier will penetrate to the colony and act as a contact insecticide while the paradichlorobenzene acts as a fumigant. Heating the oil before adding the paradichlorobenzene is an aid in making up the solution.

Six logs were treated. When they were examined four and six days later only four contained carpenter ants. Odor of the chemicals was quite strong when the logs were cut open. Mortalities of 0, 75, 100, and 100 per cent apparently resulted from contact with the insecticide, for the dead ants were covered with oil. Spread of the oil through the chambers was quite good, in some cases extending as much as three feet from the point of injection. There was no observable effect from fumigation.

Additional field tests will be run in the spring, chiefly in the hope that fumigation can be secured when higher temperatures prevail.

Naphthalene. Naphthalene in flake form is a cheap, readily-available, easy-to-handle material that has been recommended as a fumigant for control of various insects. Wardle (18) states that a warm, damp atmosphere with temperature limits of 74° to 104° F. is essential for successful control of the common red spider, Tetranychus telarius. The vapor is given off slowly so the effect is extended over a long period of time.

At Pack Forest the method of treatment was the same as with paradichlorobenzene. The five treated logs were cut open 12 and 13

days after treatment and all contained thriving carpenter ant colonies. With the exception of two ants in one colony, all were alive.

The test showed that, under the conditions tested, fumigation with naphthalene is an ineffective method for control of carpenter ants. No additional tests with this material are planned.

Naphthalene and fuel oil (27API), 3/4 lb. to 1 gallon). A similar mixture has been used to advantage in experimental control of the western pine beetle in ponderosa pine (17). The principle of control is the same as with paradichlorobenzene and fuel oil. Mixture of the two materials is best accomplished when the oil is heated.

Treatment on October 23 was by injection of the liquid into holes bored into four logs. When these logs were opened four and six days later, only three were inhabited by carpenter ants. Mortality of these ants was estimated at 10, 80, and 100 per cent. The dead ants were covered with oil, from which it was concluded that the lethal effect had been through contact. There were no evidences of death by fumigation.

In the tests with western pine beetle (17) it was found that temperature had an important bearing upon ultimate mortality. Perhaps, if the test had been prolonged at higher temperatures, the results would have been more satisfactory. Additional tests with this material will be made in the spring of 1938.

Turpentine. Turpentine acts as a contact insecticide. Its powers of wood penetration are considerable and, for this reason, it has been recommended for control of Lyctus in finished wood products. Action upon interior finishes is not detrimental.

Five logs that were treated on October 21 were cut open six days later and found to contain four colonies of Camponotus. Mortality was estimated at 50, 75, 99, and 100 per cent. Insecticidal effect of turpentine appeared to be by contact, for all of the dead ants were covered with an oily film. The survival in these tests was in the upper chambers where the liquid had not penetrated.

Tests with turpentine are being discontinued because it appears to have little value as a fumigant.

Turpentine and kerosene, 9:1. Both of these materials are powerful contact insecticides. This particular combination was suggested by Dr. Wilford, who has found that most interior finishes are not harmed by it.

Five logs were treated, but only four contained carpenter ants when the examination was made after an interval of six days. Mortality was estimated at 0, 35, 75, and 100 per cent and appeared to be the result of actual contact with the liquid.

The principle in applying this mixture is that it will follow along the galleries, soak through the dividing walls in the colony, and kill the ants by contact. In the case of a large

colony in a home, a large amount of chemical would be required, and this with but a fair chance of success. Building timbers saturated with turpentine and kerosene would present a considerable fire hazard and in addition a pronounced odor would be present for a long time.

No marked difference in effectiveness could be noted in comparing the mixture of turpentine and kerosene with turpentine alone. Therefore, tests are being discontinued.

Ethylene dichloride. Ethylene dichloride is a colorless liquid which gives off a heavier-than-air gas with a chloroform-like odor. The gas is almost as volatile as carbon disulphide, is only slightly inflammable, and is non-toxic to human beings. It has been used successfully in the control of mound-building ants, Formica exsectoides Forel (10). Cotton and Roark (4) suggest that by adding one part carbon tetrachloride to three parts of ethylene dichloride a non-inflammable mixture is obtained.

At Pack Forest the undiluted chemical was applied in two ways: (1) as a spray upon the exposed ants and (2) as a fumigant injected into the colonies. In the contact test which was conducted on one colony, the sprayed ants became unable to walk within about two minutes. They did, however, continue to move their antennae and tarsi as long as they were observed. Fifty ants were placed in a can and thoroughly soaked with liquid. Six hours later they showed signs of recovery, but none was able to walk. Six days after treatment all but four of the smallest workers had fully recovered.

The fumigation test was allowed to run from two to four weeks, at the end of which time the logs were cut open and the colonies examined. Four colonies contained carpenter ants with estimated mortalities of 75, 95, 95, and 99 per cent. Survival of ants occurred only in chambers on the upper sides of logs where the heavier-than-air gas apparently did not penetrate well. Odor of the chemical persisted for two or three weeks.

Ethylene dichloride is a promising fumigant. For successful control it is necessary to introduce the liquid into the highest chambers and maintain the gas in the ant galleries for a considerable time. Additional tests both in the field and in homes will be made. Combinations of ethylene dichloride with carbon tetrachloride will be tested in order to secure a fumigant that is free of fire hazard. In the literature (4) this mixture was found to be more toxic to insects than either component when used separately.

Dichloroethyl ether and water, 60 cc. in 1 gallon.

Dichloroethyl ether is a colorless liquid with a strong, characteristic ether odor. Successful control of wireworms (3) and sod webworms (16) has been obtained by using it in dilute solutions, 10 to 20 cc. per gallon of water. When more than 30 cc. per gallon are used, the excess has to be emulsified. This was the case at Pack Forest.

At the end of seven days five logs that had been treated with this mixture, all contained living carpenter ants. Mortality

at that time was estimated at 10, 10, 20, 35, and 95 per cent. In the case of high mortality the colony was localized in old cerambycid galleries in sound wood, a situation that afforded an ideal opportunity for fumigation. Undoubtedly most of the galleries in this colony were flooded during treatment. Odor of dichloroethyl ether was pronounced in all colonies during the final examination.

There is a possibility that, had the test been continued, or had it been conducted when temperatures were higher, the mortality would have been greater. It is probable, however, that most of the lethal effects had been spent by the time the colonies were examined, for in the tests with sod webworms (16) complete kill was secured within 48 hours.

The persistent, strong odor of ether makes the use of this chemical in homes of doubtful practicability. No further tests are planned.

Dichloroethyl ether. Undiluted dichloroethyl ether was tried with the thought that it might be a more effective fumigant than when diluted with water.

Seven logs were treated, six of which contained Camponotus. One colony was torn apart and the exposed ants were sprayed with dichloroethyl ether by using a hand sprayer. Chemical was injected into the chambers in the other logs.

For several minutes after being sprayed with dichloroethyl ether the ants did not appear to be more distressed than would

have been the case had they been sprayed with water. Then activity began to slow down, the abdomen drooped, and finally, within 15 minutes of the initial application, the ants curled up and were unable to walk. Fifty ants were placed in a baking powder can and thoroughly soaked. These continued to move their legs and antennae for at least two hours. Two days after treatment the colony was revisited and many dead ants were found. Whether any recovered is not known.

Mortality in the injected logs was 0, 0, 10, 75, and 100 per cent. Despite the fact that a very strong odor of ether was present 13 days after treatment, dichloroethyl ether seems to be a poor fumigant. The odor was so pronounced that it was evident in the woods as far as five chains from the treated colonies. The ants seemed to be anaesthetized rather than killed by the fumes.

The test with undiluted dichloroethyl ether indicates that it is a rather poor material for carpenter ant control because of ineffectiveness and because of the persistent strong odor. Tests with it are discontinued.

Hexachloroethane. Hexachloroethane is a solid that volatilizes slowly at ordinary temperatures. It has been used as a soil fumigant and as a substitute for naphthalene and paradichlorobenzene, as well as for experimental control of mosquito larvae (12). The gas, which is harmless to man and higher animals, enters the respiratory system of insects and has a paralyzing lethal effect.

At Pack Forest five logs were treated by the same method as with paradichlorobenzene. Two weeks later the logs were cut open and three were found to contain carpenter ants. No mortality was found in any case. Ants were thriving within three inches of the chemical which was still present and giving off a slight but characteristic odor.

Under the conditions tested, hexachloroethane has no value as a fumigant in control of carpenter ants. No further tests are contemplated.

DISCUSSION AND CONCLUSIONS

Three species of Camponotus--C. laevigatus, C. maculatus vicinus var., and C. herculeanus modoc--were included in the tests at Pack Forest. Of these only C. maculatus vicinus var. is known to infest homes in the Pacific Northwest. Lasius niger sitkaensis, a common inhabitant of homes, was not tested.

It is considered unlikely that any one material or type of treatment will be unfailing in the control of carpenter ants in homes, for much depends upon the nature of the infestation. When a colony can be located and fully exposed without considerable difficulty, carpenter ants can be exterminated quickly and efficiently by spraying the ants with pyrethrum extract in light oil. There are a number of proprietary products on the market that are of this general class. Considerable variation exists among these materials both as to specifications for the oils and the percentage of pyrethrum present. Standard Oil Fly Spray, purchased on the open market, was tested as being representative of the commercial oil sprays that are available for general use. It was found to be fully effective when all of the ants were covered with the liquid.

Three baits--Paris green and hamburger; Paris green and brown sugar; and thallium sulphate, honey, and sugar--were tested. No carpenter ant mortality was observable. It is concluded that either the baits were improperly applied or the ants were being

supplied with abundant aphid honeydew; consequently, they avoided the bait. Additional tests are necessary in order to determine the effectiveness of baits for carpenter ant control.

Sodium fluoride and sodium fluosilicate were dusted into ant runways to act as a stomach poison. Application was made under unfavorable climatic conditions--wet, cold, fall weather--and no definite conclusions are justified. Only a few ants were killed in three colonies treated with sodium fluoride, but this is considered significant since the principle of control is that the poison is carried by the ants to the entire colony. Therefore, although the kill was very low in the field test, sodium fluoride is considered as a very promising material.

When ant colonies are well localized it is possible to inject a fumigant, contact insecticide, or combination of the two into the galleries and exterminate the ants, provided that all of the colonies are reached with the chemical. Fourteen chemicals were tested separately or in combination to determine their effectiveness when introduced into a carpenter ant colony. Of the materials tested, carbon disulphide, carbon tetrachloride, paradichlorobenzene in fuel oil, naphthalene in fuel oil, and ethylene dichloride gave the best results. It appears that a mixture of ethylene dichloride and tetrachloride would be nearly an ideal insecticide of this type, provided it is effective. Such a mixture would be fairly cheap, easily procurable, easily applied,

non-inflammable and non-explosive, non-toxic to human beings, and of non-offensive odor. The two constituents gave good results separately, but the combination has not been tested.

MacAloney and Hosley (10) found that fumigation was most effective during damp, cold weather when all of the ants were present in the colony. This is essentially a compromise measure in which insecticidal toxicity of the fumigant is sacrificed in some degree for presence of all the ants. At Pack Forest tests with fumigants were conducted late in the fall and the mortality resulting from fumigation was low in most instances.

A number of materials suggested in the literature, such as chloropicrin (8), refined creosote (7), and gasoline (5), have been excluded from the tests as being unsuited for use in homes.

RECOMMENDATIONS

It is the recognized purpose of this study to reduce the number of suggested measures for carpenter ant control to the ones best adapted for use in homes in the Pacific Northwest.

Field tests in 1938 are advised for the following materials:

Pyrethrum contact spray
Sodium fluoride
Sodium fluosilicate
Cube
Nicotine
Paris green bait
Carbon tetrachloride and ethylene dichloride
Paradichlorobenzene in fuel oil
Naphthalene in fuel oil

Insecticidal value of these chemicals could be tested in a Peet-Grady type of chamber, using carpenter ants as the test insects. This would reduce the number of colonies required for the experiments--a highly desirable feature. Testing in a chamber under uniform conditions would give a better basis for comparing the effectiveness of the several chemicals.

Experimental control in infested homes during the spring of 1938 should be attempted with (1) sodium fluoride and (2) ethylene dichloride and carbon tetrachloride, 3:1.

Effective control measures for Lasius niger sitkaensis remain to be determined.

Time of year as a factor influencing effectiveness of carpenter ant control methods should be fully investigated.

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Figure 1. Carpenter ant colony No. 50. After this picture was taken the colony was treated with sodium fluoride dust.

TABLE I

SUMMARY OF CARPENTER ANT CONTROL TESTS, LaGRANDE, WASH., 1937.

Treatment	Duration in days	Date Treated	Date Examined	Left for Future Examinations	Amount of Chemicals per Colony	Total No. of Colonies Treated	Colonies with Ants	Colonies without ants when Reexamined	Ant Species: Camponotus laevigatus	Camponotus maculatus vicinus	Camponotus herculeanus modoc	Others	Unknown, Probably Camponotus	Effectiveness	Remarks
		8-14-37	8-14-37												
Standard Oil Fly Spray	--	8-25-37	8-25-37 9-27-37	--	1 pint	6	6	--	1	1	1	--	3	Effective	Satisfactory contact insecticide. Tests discontinued.
Sodium fluoride dust, Test 1	31	8-24-37	9-24-37	--	16 ounces	5	5	--	--	1	--	--	4	Non-effective	Improperly applied.
Sodium fluoride dust, Test 2	13 & 14	10-13-37	10-26-37 10-27-37	4 in part	6 to 12 oz.	6	6	--	2	2	1	--	1	Partially effective	Promising material. Test continuing.
Sodium fluosilicate & bentonite, 7:3	6	10-21-37	10-27-37	5 (2 in part)	8 oz.	5	5	--	1	1	--	--	3	Non-effective	Not fully tested. Test continuing.
Paris green & hamburger bait, 1:30	33	8-25-37	9-27-37	--	3 oz.	5	2 (?)	3 (?)	2	--	--	--	--	Non-effective	Not fully tested.
Paris green & brown sugar bait, 1:32	30 & 33	8-25-37	9-24-37 9-27-37	--	3 oz.	5	5	--	5	--	--	--	--	Non-effective	Not fully tested.
Thallium sulphate bait	33	8-25-37	9-27-37	--	1 oz.	5	5	--	4	--	--	1	--	Non-effective	Not fully tested. Discontinued because of Bureau policy in re. to thallium. Partially effective with Formica fusca.
Carbon disulphide	31	8-24-37	9-24-37	--	1 pt.	5	4	1	3	1	--	--	--	Partially effective	Effective when all galleries are reached. Tests discontinued.
Carbon disulphide & carbon tetrachloride, 1:3	5	10-22-37	10-27-37	--	10-20 oz.	5	4	1	2	2	--	--	--	Partially effective	" " " " "
Carbon tetrachloride	7	10-20-37	10-27-37	--	8-12 oz.	5	4	1	3	1	--	--	--	Partially effective	" " " " . To be retested.
Carbon tetrachloride & Pyrocide 20, 4:1	6 & 7	10-20-37	10-26-37 10-27-37	2 in part	6-8 oz.	5	4	1	3	1	--	--	--	Non-effective	To be tested as contact insecticide.
Orthodichlorobenzene	26	9-29-37	10-25-37	--	12-24 oz.	6	4	2	2	2	--	--	--	Partially effective	Effectiveness poor. Tests discontinued.
Orthodichlorobenzene & cottonseed oil, 1:1	5 & 7	10-22-37	10-27-37 10-29-37	--	8-10 oz.	5	4	1	3	--	--	1	--	Partially effective	Effectiveness fair. Tests discontinued.
Trichlorobenzene	13	10-12-37	10-25-37	--	18-24 oz.	6	6	--	6	1	--	--	--	Partially effective	Effectiveness poor. Tests discontinued.
Paradichlorobenzene, Test 1	31 & 34	8-24-37	9-24-37 9-27-37	--	16 oz.	5	5	--	2	3	--	--	--	Partially effective	Effective control indicated. Improperly applied.
Paradichlorobenzene, Test 2	13	10-13-37	10-26-37	5 (3 in part)	6 oz.	5	5	--	3	1	--	--	1	Partially effective	Test continuing.
Paradichlorobenzene & fuel oil, 180 gr. to 1 gal.	4 & 6	10-23-37	10-27-37 10-29-37	--	16-32 oz.	6	4	2	2	2	--	--	--	Partially effective	Effective when all galleries are reached. To be retested.
Naphthalene	12 & 13	10-13-37	10-25-37 10-26-37	--	5 oz.	5	5	--	3	2	--	--	--	Non-effective	Useless. Tests discontinued
Naphthalene & fuel oil, 3/4 lb. to 1 gal.	4 & 6	10-23-37	10-27-37 10-29-37	--	16-24 oz.	4	3	1	3	--	--	--	--	Partially effective	Effective when all galleries are reached. To be retested
Turpentine	6	10-21-37	10-27-37	--	12-20 oz.	5	4	1	4	--	--	--	--	Partially effective	Effective when all galleries are reached. To be discontinued.
Turpentine & kerosene, 9:1	6	10-21-37	10-27-37	--	12 oz.	5	4	1	3	--	1	--	--	Partially effective	" " " " "
Ethylene dichloride	13,15,26,& 28	9-29-37	10/12,14,25,27/37	--	12-24 oz.	6	5	1	3	2	--	--	--	Partially effective	Effective when all galleries are reached. To be retested.
Dichloroethyl ether, diluted (60 cc. in 1 gal.)	13	10-12-37	10-25-37	--	12-24 oz.	7	6	1	2	3	1	--	--	Partially effective	Effectiveness poor. Tests discontinued.
Dichloroethyl ether, undiluted	7	10-22-37	10-29-37	--	24-32 oz.	5	5	--	5	--	--	--	--	Partially effective	Effectiveness poor. Tests discontinued.
Tetrachlorethane	13 & 15	10-12-37	10-25-37 10-27-37	--	1-2 oz.	6	3	3	1	--	2	--	--	Non-effective	Useless. Tests discontinued.
Totals						133	113	20	68	26	6	2	12		